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Construction details affecting flanking transmission in wood framed multifamily dwellings

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Abstract

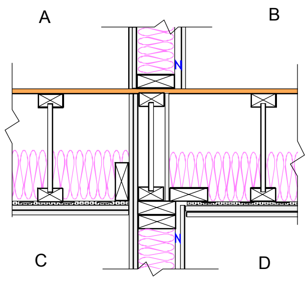
The measurement phase of a three-year project at the National Research Council Canada to study flanking transmission in wood-framed construction under controlled conditions was recently completed. The focus was horizontal and vertical flanking paths involving the wall/floor junction in multifamily buildings built to resist wind or seismic loads. This paper reports on the effect of joist orientation (relative to the wall/floor junction), junction blocking details, joist type (solid lumber vs. wood-I joists), and wall framing (double stud, single stud or single stud shear walls) for airborne excitation. Significant effects were observed between rooms separated by the partition wall when subfloor continuity across the junction was changed, when joist orientation was changed from parallel to the wall to perpendicular, and when wall framing was changed from single to double stud. For both horizontally and vertically separated rooms, the dominant flanking path typically involves the floor surface, if it is simply a layer of plywood or oriented strand board. Data are presented showing the effectiveness of toppings to control flanking transmission involving the bare floor. (INTER-NOISE companion paper - *Vibration response of floors and the effectiveness of toppings to control flanking transmission*). Estimates of the flanking sound insulation for the various paths are compared and their importance ranked.

1. Introduction

The National Research Council Canada has recently completed a study of flanking transmission in wood-frame construction. This study, carried out in the Flanking Test Facility, focused on wall/floor junctions in multifamily buildings built to resist wind or seismic loads. The wall and floor specimens divide the test facility into four rooms (labeled A, B, C, and D in the figures) and is designed to minimize all flanking paths involving surfaces other than those of the test specimens.

2. Results

The influence of joist orientation was tested both with wood-I joists and with solid lumber joists. Figure 1 shows the two constructions used with wood-I joists. The partition wall was a single stud wall with glass fiber insulation. There were two layers of 16 mm gypsum board attached directly to the studs in rooms A and C, and 1 layer of 16 mm gypsum board attached via resilient channels to the other side. The floor comprised 18 mm OSB subfloor, 300 mm wood-I joists, glass fiber insulation, resilient channels, and two layers of 16 mm gypsum board. The OSB subfloor was continuous under the partition wall in both cases. In the case with the joists perpendicular to the partition wall, the joists were continuous under the wall. When the joists were parallel, blocking was provided by continuing the gypsum board on the room C side to the under side of the subfloor, and by adding a layer of gypsum board to the room B side of the joist at the junction. With the joists perpendicular to the wall, blocking was achieved by the insertion of sections of a wood-I joist at the junction.



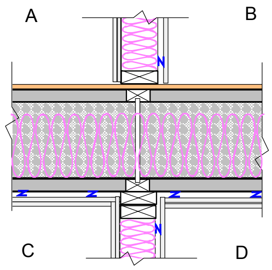
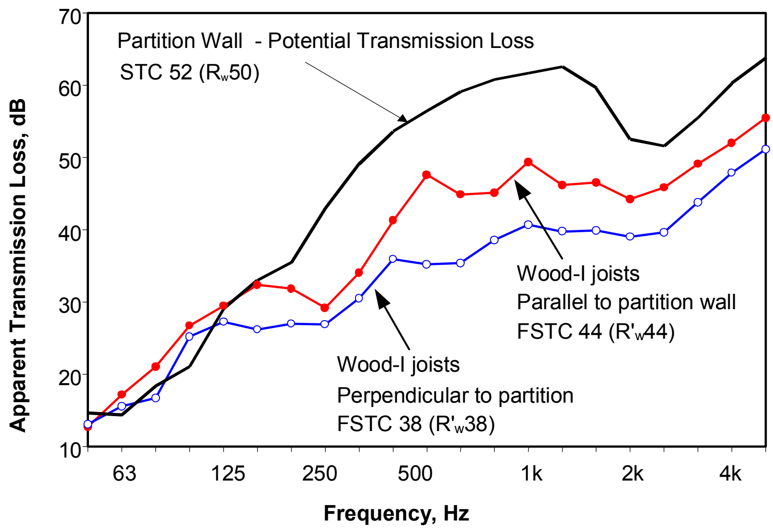


Figure 1: Floor-wall junction details for constructions with wood-I joists.

It is clear from Figure 2 that the apparent transmission loss between rooms A and B is well below that expected for this wall construction. Determination of flanking paths through a series of measurements with different surfaces shielded, showed that the floor-floor path between rooms A and B limits the sound transmission, and that floor paths in room B control the transmission for frequencies above 160 Hz. Clearly, flanking transmission is strongest with joists perpendicular to (and continuous under) the party wall. In both cases, improving the party wall would not appreciably affect the apparent transmission loss.



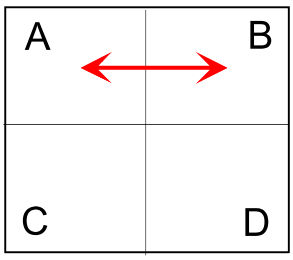


Figure 2: Apparent transmission loss between rooms A and B for the two joist orientations. The maximum transmission loss expected for the wall construction is shown for comparison.

Figure 3 shows the constructions used to investigate the effect of joist orientation when only the OSB subfloor was continuous under the partition wall. The constructions had solid lumber joists. The partition wall had double studs with glass fiber insulation in the cavities and two layers of 16 mm gypsum board attached directly to each side. The floor comprised 16 mm OSB subfloor, 38x235 mm wood joists, glass fiber insulation between the joists, wood strapping, resilient channels, and two layers of 13 mm gypsum board. When the joists were parallel to the wall, the floor framing had a double header atop each wall leaf. When the joists were perpendicular to the wall, there was a single header terminating the joists atop each wall leaf. The OSB subfloor was continuous under the partition wall for both cases.

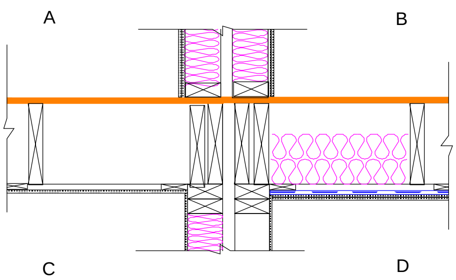


Figure 3: Floor-wall junction details for constructions with solid lumber joists.

Figure 4 shows that both orientations of the joists gave similar results, in this case. The construction with the joists perpendicular to the partition wall had only a slightly higher apparent transmission loss. This was quite different from the results with continuous wood-I joist, suggesting that the joist orientation is not a significant factor when the joists are not continuous. When the joists are perpendicular to, and continuous under, the partition wall, vibrational energy could propagate in both the subfloor and the joists and the floor-floor paths are particularly strong.

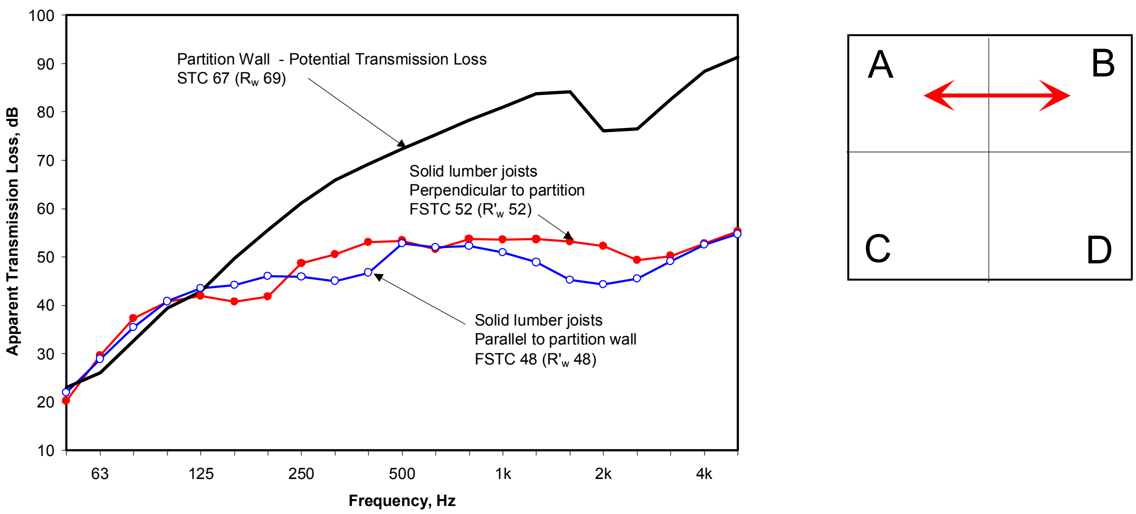
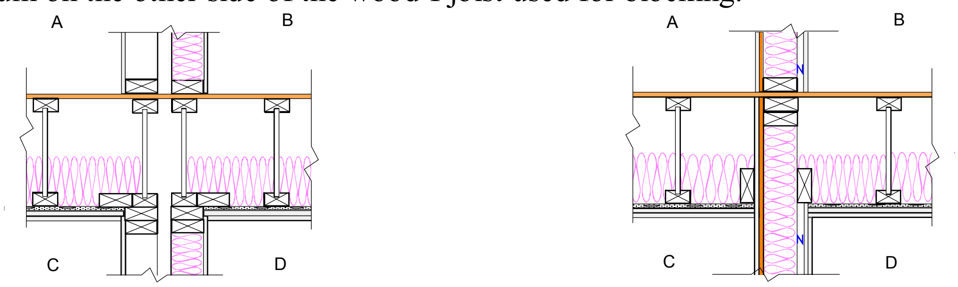


Figure 4: Apparent Transmission Loss between rooms A and B for all flanking paths involving the floor in room B.

Clearly any attempt to improve the performance of these constructions must focus on elimination of paths involving the floor. This can be done either by reducing the energy getting into the floor structure or by increasing the attenuation at the floor/wall junction. This paper will look at how changes at the floor/wall junction affect the flanking paths involving the floor. The INTER-NOISE companion paper [1] will discuss ways to reduce the energy input to the floor structure.

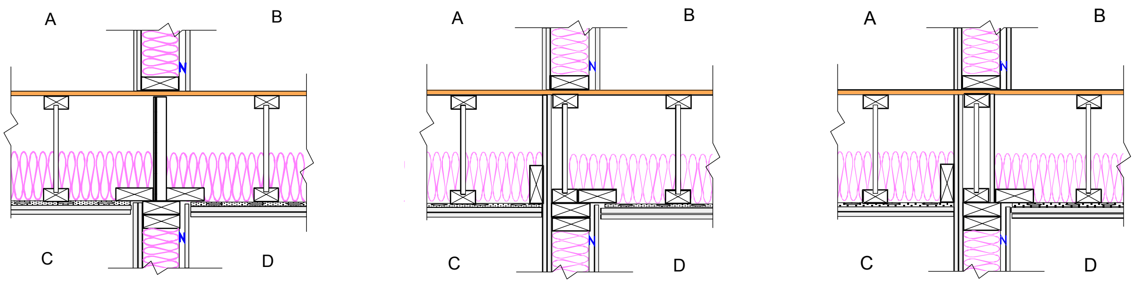
Figure 5 and Figure 6 show the three wall constructions including three variants of the joint detail used to determine the influence of the floor/wall junction on the flanking paths.

- **Double stud wall** - Double stud wall with gypsum board attached directly on both sides. A wood-I joist was placed under each wall leaf.
- **Single stud shear wall** - Single stud shear wall with a direct attached OSB shear membrane and single layer of gypsum board on one side and a single layer of gypsum board attached via resilient channels to the other. The framing of the lower wall extended through the floor to the underside of the OSB subfloor.
- **Single stud wall A** - Single stud wall with two layers of gypsum board attached directly to the studs on one side and one layer of gypsum board attached via resilient channels on the other. A 32 mm thick rimboard was used to provide blocking under the partition wall.
- **Single stud wall B** – This was a variant of single stud wall A. In this case a wood-I joist is used to provide blocking and the direct attached gypsum board is extended up to the underside of the OSB subfloor.
- **Single stud wall C** – This was a variant of single stud wall B with an addition layer of gypsum on the other side of the wood-I joist used for blocking.



Double stud wall **Single stud shear wall**

Figure 5: Sketches showing the floor/wall junction details for the double stud and single stud shear walls



Single stud wall A **Single stud wall B** **Single stud wall C**

Figure 6: Sketches showing the floor-wall junction details for the three variants of the single stud wall

Figure 7 shows the apparent transmission loss measured between rooms A and B. In all cases the transmission is dominated by paths involving the floor, however there are some minor differences. The double stud wall provides a larger impedance change at the wall/floor junction, which results in higher transmission loss, particularly at high frequencies.

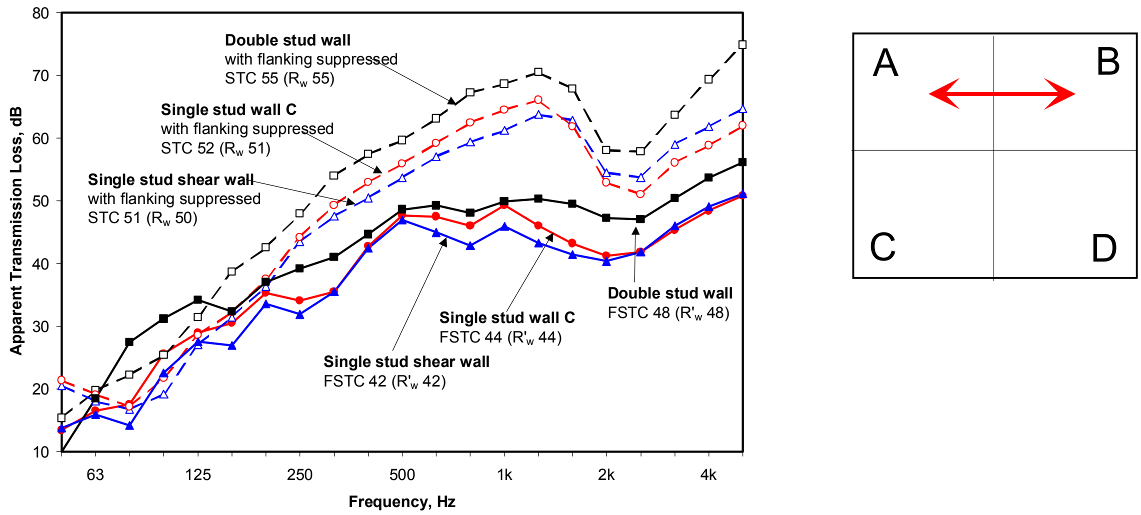


Figure 7: Apparent transmission loss between rooms A and B for the double stud wall, single stud shear wall, and single stud wall C. Also shown is the transmission loss expected for each wall if all flanking paths were suppressed.

The apparent transmission loss in the vertical direction between rooms A and C, shown in Figure 8 indicates that there is very little difference between the double and single stud walls. This is consistent with the direct path through the floor being the dominant path. The construction having the single stud shear wall is noticeably lower. This is because the direct coupling between the subfloor and the studs of the wall in room C enhances the flanking paths involving the wall in room C making it a limiting path for this construction.

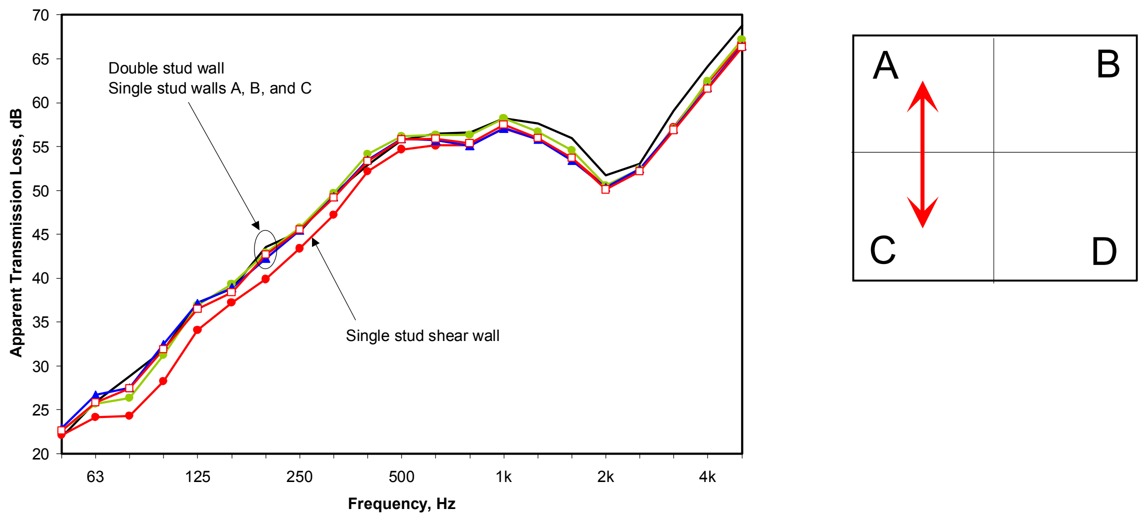


Figure 8: Apparent transmission loss between rooms A and C for all five constructions shown in Figure 5 and Figure 6.

Figure 9 provides a more detailed examination of the apparent transmission loss between rooms A and B. Between 500 – 2000 Hz there is a small but systematic change in the attenuation through the floor/wall junction caused by the junction details. The noticeably better sound insulation with the double wood stud wall is due to the discontinuity introduced by the small section of OSB between the head plates of the double wood stud walls. The variation between the single wood stud walls is not large and is probably indicative of the magnitude of change that is possible by modifying the details of the floor/wall junction.

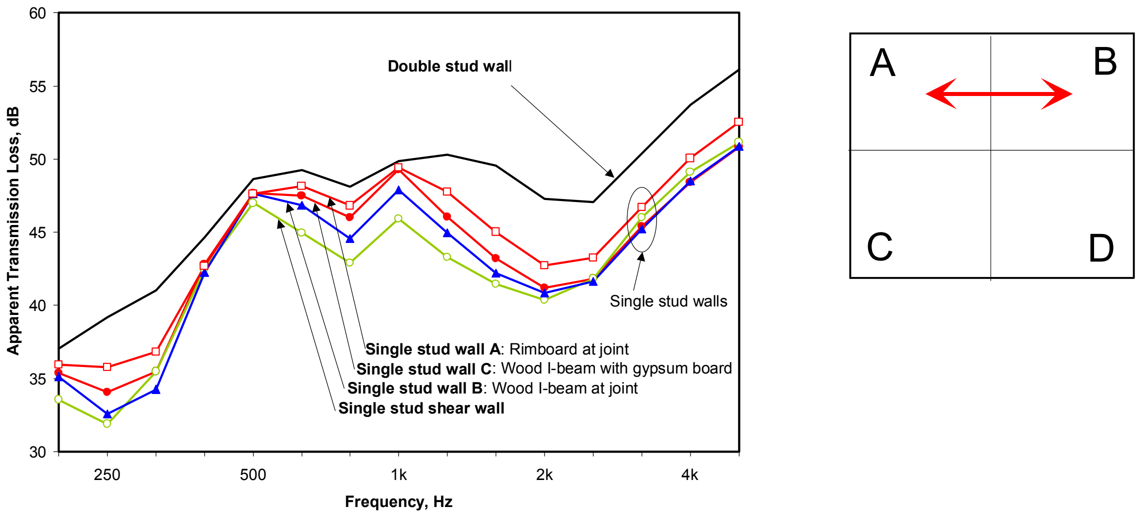


Figure 9: Apparent transmission Loss between rooms A and B showing the difference among the three walls and junction variants

The wood-I joists commonly used in current construction are lighter than traditional solid lumber so it was of interest to consider what effect this would have on the performance of the floor/wall junction. The construction details are shown in Figure 10. The 300 mm wood-I joists of the first case were replaced with 38x235 mm solid lumber joists with strapping. Both floors had the 19 mm OSB subfloor continuous under the partition wall and two layers of 16 mm gypsum board attached via resilient channels.

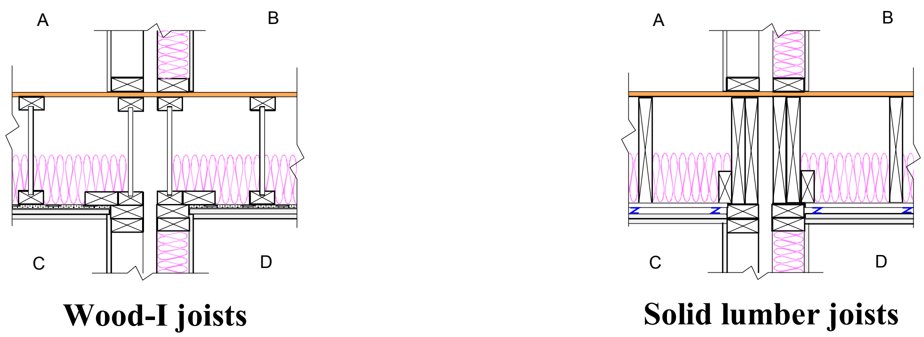


Figure 10: sketches showing the floor-wall junctions details for two floors using solid lumber joists and wood-I joists.

Figure 11, shows that the apparent transmission loss between rooms A and B is quite similar despite the changing the joists from wood-I-joists to solid lumber. In both cases the transmission loss is dominated by flanking paths involving the floor, in particular the floor-floor path. When viewing the changes in Figure 11 it is important to realize that changing the joist type will affect three components in the transmission path. These are the incident power on the junction, junction transmission, and radiation in the receiver room, none of which can be fully separated. Thus, trends like increased high frequency attenuation due to increased rotary interia of the double dimensional-lumber header at the joint may not be evident as it may be masked by changes in the incident power.

Figure 12 shows that the effect of joist type is not overly important for direct transmission, especially when expressed as a single number rating. This is consistent with earlier findings [2]. The floor with solid lumber joists does provide increased performance in the range 63-125 Hz. This may be due to increased mass of the floor system, differences in stiffness and method of attaching the resilient channels. High frequency differences, above 2000 Hz, may be due to increased damping of the joists caused by the different requirements for attachment at the supporting walls. Changes observable in the low and high frequencies for direct transmission (Figure 12) do not correlate with those for flanking transmission (Figure 11). This suggests that joist type affects direct and flanking transmission differently.

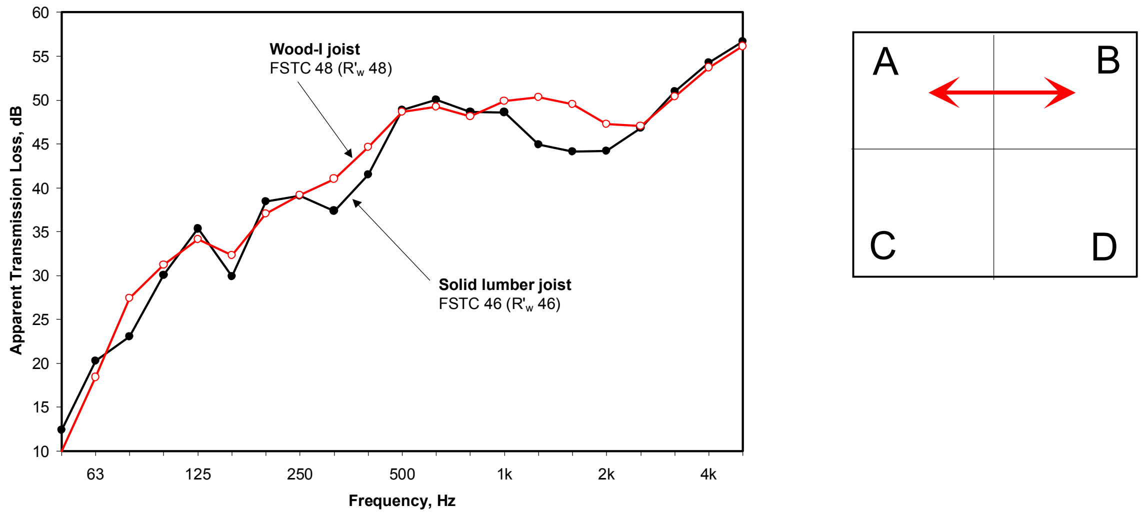


Figure 11: Apparent transmission loss between rooms A and B constructions using solid lumber and wood-I joists.

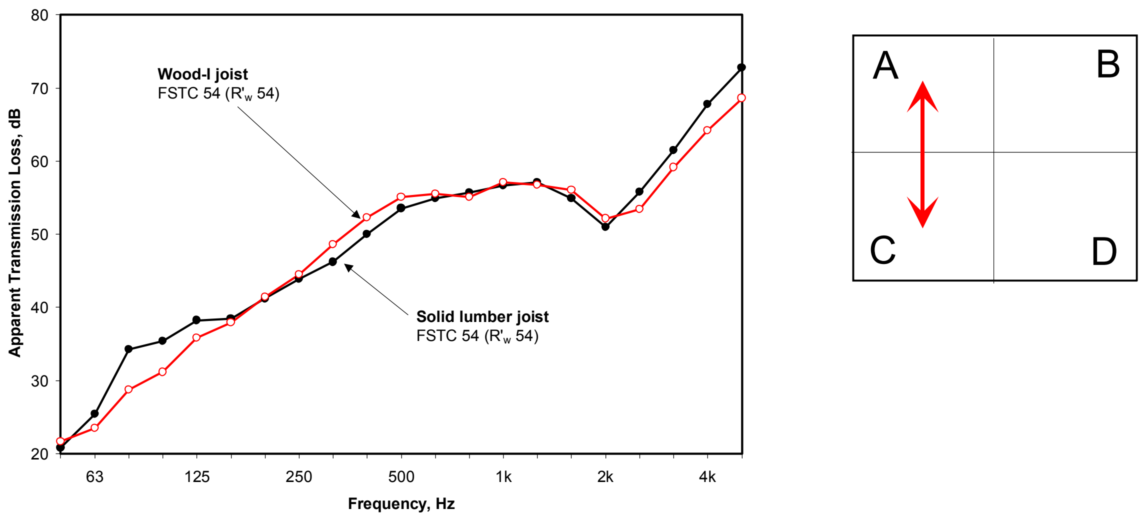
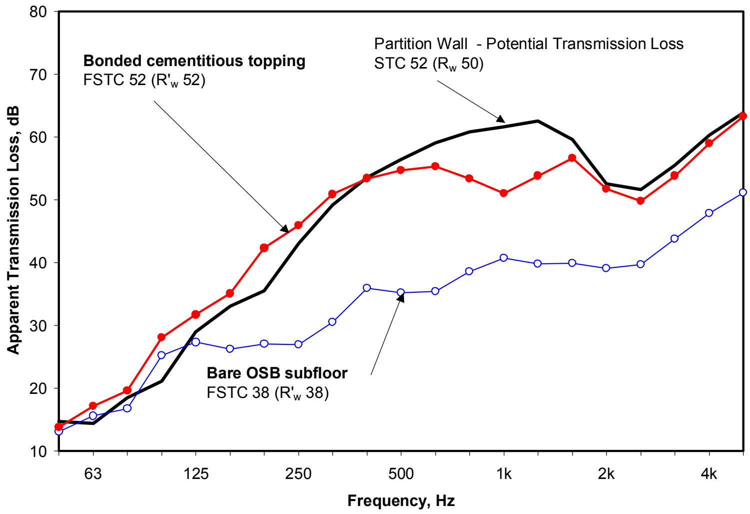


Figure 12: Apparent transmission loss between rooms A and C constructions using solid lumber and wood-I joists.

This floor construction would not be used in building without some form of finished surface or topping. The affect of adding a topping will be discussed in detail in the INTER-NOISE companion paper [1], but some idea of the potential benefit of a topping can be seen in Figure 13. In this case a 25 mm gypsum concrete topping has been applied directly to the subfloor. This is a self-leveling material that forms a bond with the gypsum board wall surfaces and the subfloor. It also has a tendency to flow under gypsum board surfaces mounted on resilient channels and form a bond with any exposed sole plate, effectively shorting the resilient channels at the bottom of the wall. Nevertheless this topping proves quite effect in reducing the influence of paths involving the floor. Figure 13 shows the affect of the topping on the apparent transmission loss for the case with continuous wood-I joists perpendicular to the partition wall. In this case the full potential of the partition wall is realized except for bands about 1000 Hz, the coincidence frequency of the combined topping/subfloor system.



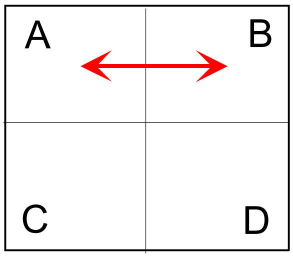


Figure 13: The Apparent transmission loss between rooms A and B showing the effect of adding a 25 mm gypsum concrete topping bonded to the subfloor.

3. Conclusion

A study of flanking transmission in wood frame construction has found that for airborne excitation the floor/wall junction in multifamily buildings provides serious structural flanking when a continuous subfloor is used to provide resistance to wind or seismic loading. In this situation the floor – floor path becomes the dominate transmission path irrespective of the joist orientation relative to the common wall. Although the junction attenuation can be affected slightly by modifications to the joint details, the only practical solution lies in reduction of the input energy by the use of a floor topping.

The direct path dominates in the vertical direction, although the path from the wall in the room above to the wall in the room below may become a limiting path if all four walls of room are attached directly to the studs. This is particularly true if the floor is improved by the addition of extra insulation in the cavity or gypsum board to the ceiling rather than by the addition of a topping.

References

1. T. R. T. Nightingale, R. E. Halliwell, and J. D. Quirt, "Vibration response of floors and the effectiveness of toppings to control flanking transmission", INTER-NOISE 2002
2. A.C.C. Warnock, J.A Birta, Internal Report IRC-IR-811, National Research Council Canada, July 2000.

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